Meeting in the Middle: The Challenge of Meso-Level Integration

An International Workshop
October 17-20, 2000
Ispra, Italy

Edited by: William J. McConnell and Emilio F. Moran

Contributing Authors: Eduardo Brondizio, Ruth DeFries, Rheyna Laney, John S. Latham, Alejandro Leon, Laura Schneider, Peter Verburg, and Stephen J. Walsh

Workshop Participants: Listed in Annex

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LUCC International Project Office
c/o UCL/GEOG
Place L. Pasteur 3
B-1348 Louvain-la-Neuve
Belgium
Fax: 32-10-47-28-77
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List of Acronyms

AFRICOVER	Africa Land Cover Mapping Project
AVHRR	Advanced Very High Resolution Radiometer
CIESIN	Center for International Earth Science Information, Columbia University
CLUE	Conversion of Land Use and its Effects Project
CORINE	Co-ordination of Information on the Environment Programme of the EU
DIS	Data and Information System of the IGBP
EU	European Union
FGDC	US Federal Geographic Data Committee
GAC	Global Area Coverage resolution of AVHRR instrument
GEMS	Global Environmental Monitoring System of the UN
GLUCC	Global Land Use and Cover Classification Committee (IGBP)
GVM	Global Vegetation Monitoring Unit of the SAI
IGBP	International Geosphere-Biosphere Programme
IHDP	International Human Dimensions Programme
ITC	International Institute for Aerospace
ITE	Institute for Terrestrial Ecology
JRC	Joint Research Centre of the EU
LAC	Local Area Coverage resolution of AVHRR instrument
LCCS	Land Cover Classification System
LUCC	Land Use and Cover Change Project (IGBP and IHDP)
MODIS	Moderate Resolution Imaging Spectrometer of NASA
MRLC	Multiple Resolution Land Characteristic Database (USGS)
NASA	US National Aeronautics and Space Administration
NOAA	US National Oceanic and Atmospheric Administration
NSF	US National Science Foundation
SAI	Space Applications Institute of the JRC
SPOT	Systeme pour l'Observation de la Terre
SYPR	Southern Yucatan Peninsular Region Project
TM	Thematic Mapper instrument on Landsat satellites
TREES	Tropical Ecosystem Environment Observation by Satellite Project of the EU
UN FAO	United Nations Food and Agricultural Organization
UNEP WCMC	World Conservation Monitoring Centre
USGS	US Geological Survey

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1. Introduction

This report constitutes the proceedings of an international workshop held in Ispra, Italy, October 17 to 20, 2000, entitled “Meeting in the Middle: The Challenge of Meso-Level Integration.” The workshop was organized by the Focus 1 Office of the Land Use and Cover Change Project (LUCC), which is a joint core project of the International Human Dimensions of Global Change Programme (IHDP) and the International Geosphere-Biosphere Programme (IGBP). The workshop was hosted by the Global Vegetation Monitoring Unit (GVM) of the European Commission’s Joint Research Centre (JRC), with support from: the National Science Foundation’s (NSF) Directorate for Social, Behavioral and Environmental Sciences; the National Aeronautics and Space Administration’s (NASA) Land Use and Cover Change Program; and Indiana University’s Office of Research and University Graduate School (RUGS).

The workshop was called for in the LUCC Implementation Strategy, as part of the overall effort to glean knowledge generated in the thousands of prior and ongoing research efforts aimed at understanding land use and cover change throughout the world, and to guide future efforts. The comparability of information from these studies is a fundamental prerequisite to this effort to codify the state of knowledge and facilitate the construction of a science of global change. The workshop was one step in a larger effort being undertaken by LUCC in collaboration with many others, especially the Food and Agricultural Organization of the United Nations (UN-FAO).

The workshop brought together some two dozen scientists involved in land use and cover change research from a broad range of geographical and institutional perspectives for three and a half days to examine the progress to date in harmonizing land use and cover classification, and to explore the remaining challenges. A list of the participants and the workshop agenda can be found in Annex 1 of this report.

The report is organized in four sections: following this introduction is a brief rationale for harmonization and a presentation and discussion of fundamental concepts and terms; the next section presents progress made to date in harmonizing land cover research, under the auspices of the FAO/Africover project, and an assessment of the LCCS software by the workshop participants; this is followed by a more detailed discussion of the challenges we face in harmonization; and finally, the last section offers conclusions and recommendations.

2. Rationale and Fundamental Concepts

This section presents a brief rationale for the harmonization of land use and cover classification schemes, and presents some of the fundamental concepts treated in the remainder of the report. The rationale and challenges to harmonization are taken up in more detail in Section 4 of the report.

2.1 The Rationale for Harmonizing Land Use and Land Cover Classifications

There is major interest in, and need for, more accurate and consistent information on land cover and land use and on the interrelations between them:

At global and regional levels, land cover and land use data are urgently needed for global change research and modeling and for the crafting and implementation of international policy, such as the UN Framework Convention on Climate Change, the Convention on Biological Diversity and the Convention to Combat Desertification.

At regional and national levels, better information is needed for macroeconomic studies, for the modeling of policy scenarios, and to forecast environmental impacts of policies.

At the national level, statistics on agriculture, fisheries, forestry, etc., are often not consistent, and multiple land use is usually ignored.

At the national and local levels, while soil/terrain and climate information structures are quite sufficient for land evaluation and land use and agricultural planning, there is no agreed system to describe production systems.

Given the high costs associated with environmental survey and mapping, the optimal use of information is a growing concern. Ideally, existing data could serve multiple uses. Unfortunately, however, land cover and land use databases are not generally developed to meet multi-user requirements; rather, data specifications are driven by a particular application. Consequently, the classification schemes and map legends used to communicate basic information such as land cover and/or land use are generally not comparable one to another. The result is a diversity of systems and nomenclatures to describe the land surface and the uses to which it is put.

Until recently there was no agreement world-wide, or even at European or national levels, on precisely what constitutes land use or land cover, or on how to define them. As a result, many classification systems and innumerable map legends exist, and maps and statistics from different countries, and in many cases even from the same country, were found to be incompatible with each other. The consequences of these differences have been graphically demonstrated, *inter alia*, by Wyatt and others (1994) and DeFries and Townshend (1994). A major factor contributing to the observed problems stems from differences in nomenclature, and especially in differences in the way in which class boundaries are defined.

The heart of the LUCC enterprise is the gleaning and codification of knowledge gained in hundreds or thousands of research efforts to date and guiding future efforts. The holy grail of LUCC is the derivation of general principles from this wealth of case study research; this requires a certain degree of comparability among the case studies, and this requirement is singled out clearly in the LUCC Implementation Strategy. One of the fundamental aspects of such case studies about which comparability is needed is the taxonomy of the land cover types and the land use practices that alter them.

2.2 Fundamental Concepts

A rich terminology is used in land use and cover change research, and the discussions of the workshop made it clear that the precise definitions of many key terms remain unsettled. This section presents the concepts, and discusses the proposed definitions, along with some of the confusion surrounding their usage. The concepts include: land use and land cover; classification; legend; scales and levels.

Land *Use* and Land *Cover*

Central to the subject matter of all land information systems are the concepts of land use and land cover. The distinction between them is fundamental, but, in practice, this distinction is all too often ignored, leading to confusion and ambiguity of many classifications, and incommensurability between them.

Land cover may be defined as the observed physical cover including the vegetation (natural or planted) and human constructions which cover the earth's surface. Land cover is the biophysical state of the earth's surface. Water, ice, bare rock or sand, and salt flats or similar un-vegetated surfaces, although strictly speaking part of the land (and water) itself and not its cover, are for practical reasons often included in land cover.

Land use, meanwhile, involves both the manner in which the biophysical attributes of the land are manipulated and the intent underlying that manipulation - the purpose for which the land is used (Turner *et al.* 1995: 20). Land-use dynamics are a major determinant of land-cover changes. Land use involves considerations of human behaviour, with particularly crucial roles played by decision-makers, institutions, initial conditions of land cover, and the inter-level integration of processes at one level with those at other levels of aggregation. Lambin and others (1999: 37) refer to the process by which land cover is modified/converted, and includes two main components:

- the activities (or operations) and inputs that are undertaken (or restricted) on a piece of land with significant land cover consequences; and
- the goals/intentions motivating these operations, including both the outputs (goods or services) that are expected, and the forces that cause land uses to occur in a certain way, at a certain time, in a certain place.

Perhaps the difference between land cover and land use is best illustrated by example. 'Forestry' is a common generic term for land uses that exploit trees. It does not necessarily imply the presence of trees. For example, after felling, the land may be bare or covered by herbaceous vegetation during early stages of succession. Conversely, in many land cover classes where trees are present, the primary use is for purposes other than forestry. Examples include parks and gardens, savanna rangeland and nature conservation areas. Land use classes relating to forests are distinguished by the purpose(s) to which the land is put, for example, 'Rubber tapping', 'Timber production', 'Fuel cropping', etc., whereas the land cover 'forest' is characterised by its physical components, such as vegetation composition, height and density.

Land cover is the observed physical cover at a given location and time, as might be seen on the ground or from remote sensing. This includes the vegetation (natural or planted) and human constructions (buildings, etc.) which cover the earth's surface. It follows that land cover may be determined by direct observation, whereas information on land use requires a statement of purpose from the person who controls or carries out the land use. Remotely sensed data, e.g. from aerial photographs or satellite images, can often be used to map land cover, for example, by identifying multi-spectral signatures characteristic of land cover types. Land use, in turn, sometimes may be correlated with actual land cover, so that land cover may be employed as a means of inferring land use.

Land use is, in part, a description of function, the purpose for which the land is being used. Definitions previously proposed include "the management of land to meet human needs", and "human activities which are directly related to the land" (Young 1994). In addition, land use constitutes a series of activities undertaken to produce one or more goods or services. The concept has proved to be a robust one, and has withstood the test of time. Building on these ideas, the Land Use Database developed by the International Institute for Aerospace Survey and Earth Sciences in the Netherlands, Wageningen University and the United Nations Food and Agricultural Organization (FAO), adopted the following definition of land use: *a series of operations on land, carried out by humans, with the intention to obtain products and/or benefits through using land resources* (de Bie *et al.* 1996).

If we adopt this definition, land use types can be described in terms of a series of activities and their associated inputs and outputs, and the forces causing this use to occur at a particular place and time. For example, the agricultural land use “Wheat field” is defined by the series of activities undertaken on specific dates to produce a crop of wheat (the output), together with the inputs required to carry out each activity. A given land use may take place on one, or more than one piece of land, and several land uses may occur on the same piece of land. Definition of a land use in this way provides very precise distinctions between land uses, and may even be used as the basis for analysis of economic and environmental impacts.

It is worth noting that there was less than full agreement on the definition of land use among the workshop participants. Many modelers, it is argued, think of land use in terms of systems, the adequate representation of which requires the inclusion of a range of components.

So, for example, a mountain grazing land use system entails not only the fields in which the animals graze, but the barnyard, the residence of the shepherd, and other physical components of the system. At the extreme, it is asserted that land use itself is not mappable. While this assertion may represent a minority view, all participants agreed that there is no simple one-to-one relationship between land use and land cover. Many examples can be offered of land covers wherein a given unit (*e.g.*, a patch of forest) may support any one of, or combinations of, several different land uses (logging concession, protected area, tourism, residential, etc.)

Classification

Classification is 'the ordering or arrangement of objects into groups or sets on the basis of their relationships' (Sokal 1974). The process of land classification is the abstract representation of physical land units using pre-defined diagnostic criteria (Choudhury and Jansen 1998). These criteria should be clear, precise, objective and, where possible, quantitative, so that the outcome would be the same whoever the user.

The result of the classification activity is a classification system. A classification system comprises a logical framework, holding the names of the classes, the criteria used to distinguish them and the relationships between classes. Classification systems may or may not be hierarchical, but hierarchies which descend from a small number of generalised categories at the higher level to a large number of more detailed categories at the lower levels are commonly used. Classification systems should be independent of spatial scale and of the means used to collect the information recorded (FAO 1997).

Legends

Legends are often confused with classifications, but there are crucial differences. Strictly, a legend is the application of a classification for a particular purpose, for example, for thematic mapping. Whereas a classification should recognise the entire universe of sets that make up its subject matter, a legend may contain only a proportion, or sub-set, of the classes in the classification from which it is derived. Some classes may be omitted; others may be combined into composite categories. Often, map legends may be specified which are not based on any explicit classification.

Unlike classifications, legends are usually dependent on the source data and on cartographic properties, such as spatial scale. A common feature of legends is the occurrence of mixed classes. Nevertheless, a good legend should contain as much helpful information as possible, in order to assist the user to understand and interpret the entity that is being depicted.

Spatial Scales and Levels of Organization

Land use and cover change are the result of many interacting processes. Each of these processes operates over a range of scales in space and time. With the term scale we refer to the spatial, temporal, quantitative, or analytic dimensions used by scientists to measure and study objects and processes. All scales have extent and resolution. Extent refers to the magnitude of a dimension used in measuring (*e.g.*, area covered on a map) whereas resolution refers to the precision used in this measurement (*e.g.*, grain size). For each process important to land use and land cover change, a range of scales may be defined over which it has a significant influence on the land use pattern (Meentemeyer 1989; Dovers 1995). These processes are driven by one or more of the *driving forces* that influence the actions of the agents of land use and cover change. Often a distinction is made between social and biophysical driving forces. Reviews of the driving factors of land use change and the range of scales at which each appears the most prominent influence are given by (Turner II, *et al.* 1993; Lambin, *et al.* 2000; and The National Research Council 1999). Often, the range of spatial scales over which the driving factors and associated land-use change processes act correspond with levels of organisation. Level refers to level of organisation in a hierarchically organised system and is characterised by its rank ordering in the hierarchical system. Examples of levels include organism or individual, ecosystem, landscape and national or global political institutions. Many interactions and feedbacks between these processes at different levels of organisations occur. Hierarchy theory suggests that processes at a certain scale are constrained by the environmental conditions at levels immediately above and below the referent level, thus producing a constraint 'envelope' in which the process or phenomenon must remain (O'Neill *et al.* 1989). Land use change research would become dramatically complicated if all hierarchical relations between all driving factors would have to be incorporated.

The above described complexity of interacting processes of land-use change suggests that finding appropriate methodologies for studying land-use and cover change is not an easy task (Wilbanks *et al.* 1999). The first important consideration that should be made is that scales of analysis usually do not correspond to levels of organisation (O'Neill *et al.* 1998). A sociological survey of political opinions, for instance, is on the organisational level of individual people, but has, at the same time, usually a spatial extent of a nation. A study of common property management in a village, on the other hand, is on a group level of organisation but on a local spatial scale. And finally, an organisation such as the World Bank may be studied as a single social entity (actor), i.e. on the micro level of organisation, and may be viewed as responding to and influencing factors on the global scale. This enables us to better analyse, for instance, that phenomena that are ‘micro’ in terms of organisational level, but that may have consequences at broader spatial (*e.g.*, regional) scales. Or the reverse, that a phenomenon such as the price of fertilizer, which is a ‘macro’ phenomenon in terms of social organisation because it is an emergent property of aggregated supply and demand, exerts an important influence on spatial scale of an individual farmers’ field.

PROPOSED GLOSSARY

Land cover: The observed physical cover, as seen on the ground or through remote sensing, including the vegetation (natural or planted) and human constructions (buildings, etc.) which cover the earth's surface. Water, ice, bare land, and salt flats or similar un-vegetated surfaces are included in land cover.

Land use: A series of operations and associated inputs on land, carried out by humans, with the intention to obtain products and/or benefits through using land resources.

Classification: The ordering or arrangement of objects into groups or sets on the basis of their relationships.

Classification system: A logical framework, holding the names of the classes, the criteria used to distinguish them and the relationships between classes.

Classifier: A diagnostic criterion used to define a class.

Legend: The application of a classification for a particular purpose, for example, for thematic mapping.

3. The Challenges

The challenge taken up by the Meeting in the Middle workshop actually comprises several related issues of harmonization, involving both horizontal and vertical integration of land cover and land use, respectively, as well as the linkages between the two. As noted in the discussion of Fundamental Concepts (Section 2.2, above) land *use* and land *cover*, while often conflated, refer to distinct characteristics of the earth's surface.

The workshop discussions recognized the following horizontal dimensions of integration:

- harmonizing classification schemes used to characterize land *cover* (*i.e.*, between two similar studies of land *cover* in different parts of the world)
- harmonizing classification schemes used to characterize land *use* (*i.e.*, between two similar studies of land *use* in different parts of the world)

as well as issues pertaining to vertical integration:

- identifying scalable *social* as well as *biophysical* effects
- variables that are linked to *pattern* and *process* (*i.e.*, linking information across studies that range from the local, to the regional, and to the global).

This section begins with a broad exploration of the ways in which the respective domains of land *use* and land *cover* analysis are often differentiated by the spatial and temporal scales at which they are observed and analyzed. It then considers in detail the particular challenges inherent to vertical integration within the land *use* domain, and explores strategies for progress, ending with a concrete example of the problems of integrating information about trajectories of agricultural change across levels of analysis.

3.1 Conceptual Issues in Harmonizing Land *Use* and Land *Cover* Information

The analysis of landscape state (*e.g.*, land cover type) and condition (*e.g.*, surface greenness) variables examined as central elements of land use and land cover characterizations are often viewed as multi-resolution concerns. In such characterizations the grain, extent, and periodicity are varied depending upon the selected unit of observation and measurement (both space and time), the research goals, as well as the research community being represented. Local and global research communities have formed to emphasize the spatial, and often temporal, imprints of their focus. And as a consequence, there have developed distinct theoretical, analytical, and informational perspectives that seem to identify each group and which have implications for land use and land cover studies in a number of important ways. These perspectives further serve to characterize each research community and to offer challenges to their meeting in the middle, at the meso-scale.

Research perspectives include, for instance, the thematic representation of primarily the biophysical domain by *global researchers*, whereas *local researchers* often integrate information across a broader set of thematic domains with emphasis on the social and/or socio-economic, but including the biophysical and the geographical as well. Governing <u>theory</u> might include hierarchy theory by global researchers and the agricultural change theory by local researchers, depending upon modeling domains and research objectives. <u>Data collection</u> techniques are also discernibly different depending upon the grain and extent of the research questions. The NOAA AVHRR system, with the possible inclusion of nested, higher spatial resolution images from Landsat, often typifies the remote sensing data gathering technologies used to support the global perspective, whereas direct observation, digital still photography and ground-based videography, aerial photography, and high resolution satellite systems such as Landsat and SPOT, and more recently Ikonos systems are often emphasized for understanding local places.

Global researchers might also employ multi-temporal data to composite views of the landscape to capture vegetation phenology, to reduce the effects of clouds and other image contaminants, and to represent coarse changes on the landscape often associated with natural- or human-induced disturbances to the landscape that have large and obvious spatial imprints. Local researchers often use time as a central element for characterizing human modifications to the landscape that may have subtle or obvious signatures of land use variation captured either through composition, pattern, or trajectory changes in land use. In addition, the global researchers are often concerned with land cover issues related for example to carbon dynamics and carbon sequestration and assimilation rates as well as the changing patterns of land cover seen through patterns and trends linked to landscape strata or time periods. Local researchers are often concerned about human behavior and the possible feedbacks and thresholds between land use and the human condition.

Global and local researchers are interested in differing landscape issues and draw upon differing theory and perspectives to achieve their goals; global researchers rely upon the natural sciences for guidance and perspective, while local researchers more routinely integrate the social sciences with the natural sciences in their studies. In addition, these two communities often utilize distinct data collection and analytical techniques, while related issues of grain and extent feed back upon these different perspectives. Defining approaches and mechanisms to synthesize these different perspectives into a consolidated research system is the essence of meeting in the middle.

A theoretical and operational mismatch exists between the perspectives of global researchers and that of local researchers, and the meso-scale appears to be a logical place to seek translation. Because global researchers work with large grains and extents as well as relatively restricted thematic domains, remote sensing systems serve to directly inform about biophysical patterns and processes (but less so) related to land cover and generally only inform in a rudimentary way about the human dimension. The local researchers are concerned with social issues related, for instance, to demographic characteristics at the household- or community-levels and the impacts of social institutions, geographic accessibility, and culture that are often secured through longitudinal social surveys, detailed remote sensing classification and change-detection involving high spatial resolution systems, GPS locations of settlement nodes, and the migration patterns of population sub-groups through follow-ups, in-depth interviews, and the like. Land use and land cover are still needed to help characterize geographic site and situation, and biophysical gradients, for example, are essential in representing resource. Linking from the local to the global may be achieved by identifying an intermediate scale to which the local researchers can consider bottom-up scaling and global researchers might consider top-down scaling in which perspectives, information, methods, and theories are synthesized and brought to bear on improving our understanding of people, place, and policy and the interrelationships of scale, pattern, and process and their signatures in land use and land cover characterizations.

Harmonization of classification schemes offers compatibility across studies that may have very different space and time signatures.

Local to regional studies and regional to global studies could be brought into classification alignment for comparability through their compatibility. The *hierarchical* nature of most classification schemes allows for the inclusion of scale-pattern-process concepts to be operationalized such that the patterns that are discerned through the classification and applied at some level within the hierarchy is dependent upon a number of processes that link in some fundamental way across themes and which are manifested at ranges of space and/or time scales. The notion of the "characteristic" landscape scales is pervasive because dominant landscape patterns are suggested through mapped land use and/or land cover patterns and the nature of their spatial organization might be ordinated around some set of events having their own timing or periodicity.

In addition to classification harmonization, we must be able to harmonize *change classes* regardless of the approach used to generate such information. Often some type of “from...to...” change information is secured as a basic feature of most of the commonly applied techniques (*e.g.,* post-classification and change-vector analysis) for finding difference between classifications generally effectuated though time differences between remote observations.

It should also be realized that most harmonization efforts focus on the spatial dimension at the expense of the temporal. Both space and time considerations are essential for making studies compatible and hence comparable. For most of the local places research time-series data are used to examine the temporal dimension and to assist in unraveling the impact of landscape pulses that are organized around intra-, inter, and decadal periods. Time-series analyses also offer information about the trajectories of land use and land cover change by conceptualizing pixel histories as a panel data set where the nature of its past landscape state or condition has implication for its current characterization -- form related to function. Single snap-shots in time may be appropriate for characterizing land cover, but it is seldom sufficient for characterizing land use because trajectories inform us about rates and directions of landscape change and they are fundamental in defining the degree of landscape modification, purpose of that modification, and possible management schemes. Time tells us about land degradation, sustainability, or its resilience. Such information can be used to assess the stability, dynamic, or "terminal" characteristics of land classes, depending upon one’s temporal resolution.

Variables developed to represent biophysical, social, and geographical domains have been scaled and iteratively modeled to ascertain the scale-dependence of their observed relationships. Multiple regression models have been used to identify the form of elements of best fit models as well as multilevel models and their degree of explanation across spatial and temporal scales. Also, the range of spatial and temporal scales in which autocorrelation and randomness occurs have been examined through the use of fractal dimensions and semivariograms. Results point to the complex interactions of modeled variables across thematic domains and the scale dependence of their relationships. Therefore, the nature of scaling variable relationships particularly including social variables derived from the local scale and extended to the meso-scale needs to be studied. Might the number of households be important at the local scale, but total population is critical at the meso-scale? Preliminary research indicates that for some selected case studies the influence of social variables is associated with fine scale variation, whereas biophysical variables are more important at coarser scales. But very few of these studies have been conducted and hence such a generalization of the predominance of biophysical over social processes at the meso-scale is premature, but important to determine.

A related issue to social-biophysical-geographical scaling is what should be the unit of observation. Thus far, up-scaling has essentially been studied through the generation of iteratively larger artificial cells within a raster domain where biophysical data, represented as continuous surfaces, and social data, represented at discrete point or polygon locations, are transformed for cartographic compatibility. Spatial agglomeration and disaggregation approaches have been used to reflect a smoothing of the landscape through the generation and subsequent re-computation of social, biophysical, and geographical variables. Serious questions remain about the ways in which different types of scaling influence the findings, and about which approaches might be most germane in a given circumstance. Using social hierarchies (*e.g.*, household, village, village cluster, administrative unit) or biophysical hierarchies (*e.g.*, watersheds or slope units) might be more appropriate than spatial agglomeration to scale social behavior and interactions of people to the land. But, such studies are very few and far between and hence no analog exists to gauge whether scaling is prone to variation as a consequence of the cartographic approach for setting scale steps and also whether results are dependent upon the temporal dimension as well. Time lags and the influence of exogenous shocks that resonate in their own frequency suggests the co-dependence of space and time on information scaling particularly in the social domain.

There are many challenges and opportunities for harmonization, not the least being concerns for accuracy of the classification, not only in the assessment of remotely-sensed categorizations of crisp and fuzzy classes and schemes, but the concern for inherent and operational errors involved in the derivation of ancillary data to support the classification into subsequent levels within the scheme's hierarchy. In addition, if time-series data are being used in either land use or land cover studies how might the accuracies of such historical views be assessed? Researchers have relied upon historical maps and photographs, terrestrial and aircraft-based products, and other data sources in order to gain retrospective views of landscapes. But social scientists have also attempted to use social surveys through retrospective questions to examine historical land patterns and past human processes that have shaped the current state or condition of the landscape. Field data collected at long-term social and/or ecological field sites have also been correlated with satellite-based landscape patterns in an effort to validate digital processing and subsequent interpretations of land use and land cover information.

Incorporating *feedbacks* and *thresholds* in population-environment interactions (connections between human behavior and landscape form and function) are another important consideration in scaling from the local to the meso-scale. Often times time lags exist in the behavior of a response variable from the effects captured through a set of descriptor variables. For example, how have crop prices affected household decisions to deforest and extensify their agriculture? How has the periodicity of above average monsoonal rains influenced farmers decisions to expand agriculture to normally marginal sites? Scaling to the meso-scale and linking across thematic domains suggests that site specific concerns of time lags is crucial and time dependent studies are equally as important as space dependent studies.

Preliminary research also suggests that in northeast Thailand young adults decide to out-migrate when the land is highly fragmented suggesting the limited availability of land and resources for agriculture as a feedback on human behavior. As for thresholds, there may be some type of trigger related to the degree of land cover fragmentation that is linked to out-migration of young adults because of the size of land parcels used or owned within this particular agricultural setting. In addition to examining the scaling to the meso-scale of feedbacks and thresholds as related to land use and land cover, it is clear that human behavior is not only related to the composition of the landscape but to its spatial organization. Pattern metrics operating at the landscape, class ,and patch levels are being used to quantify landscape conditions generally characterized through remote sensing representations categorized through classification.

What has become quite evident is that distilling research findings extending across local and global research perspectives, different study areas, and for a host of space-time scales is critical to understanding how land use and land cover varied in the past, how they are organized today, and how they may vary in the future. To understand pattern is to understand form, and hence efforts at classification harmonization moves us closer to the time when we can use land use and land cover as signatures of biophysical processes as well as keys to deciphering the influence of the human dimension on landscape structure.

3.2 The Particular Problems of Harmonizing Land *Use* Information

Research Perspectives in Land-Use Studies

Different research approaches, strongly divided by scientific discipline and tradition, have emerged in the field of human-environment interactions. Researchers in the social sciences have a long tradition of studying individual behaviour at the human-environment interface at the micro-scale, some of them using qualitative approaches (Bilsborrow & Okoth Ogondo 1992; Bingsheng 1996), and others using the quantitative models of micro-economics and social psychology.

Rooted in the natural sciences rather than the social, geographers and ecologists have focused on land cover and land use at the macro scale, spatially explicated through remote sensing and GIS, and using macro-properties of social organisation in order to identify social factors connected to the macro-scale patterns. Due to the poor connections between spatially explicit land use and the social sciences, the land use modelers have a hard time to tap into the rich stock of social science theory and methodology. This is compounded by the ongoing difficulties within the social sciences to interconnect the micro and macro levels of social organisation (Watson 1978).

The Case for Meso-Scale Integration

The following discussion first treats issues of spatial scale and organisational level relevant to land use studies (see Fundamental Concepts, above, for definitions). This is followed by a closer examination of micro-level and macro-level approaches respectively and a discussion of possible ways to achieve integration.

In our research we usually opt for one level of analysis exclusively, without considering the range of other alternatives. Often, this choice is based on arbitrary, subjective reasons and not reported explicitly (Gibson *et al.* 2000; Watson 1978). In some studies the choice for the scale of observation is based on the assumption of discrete levels of organisation, *e.g.,* communities or ecosystem patches. However, as a result of the many interacting processes, each at different levels of organisation, ecosystems and land use systems rarely or never produce a single scale that can be regarded as correct or optimal for measurement and prediction (Gardner 1998; Geoghegan *et al.* 1998; Allen *et al.* 1982; Levin 1992). Although for a specific data set optimal levels of analysis might exist where predictability is highest (Veldkamp *et al.* 1997; Goodwin *et al.* 1998), unfortunately these levels are not consistent through analysis. Therefore, it might be better not to use *a priori* levels of observation, but rather extract the observation levels from a careful analysis of the data (O'Neill *et al.* 1998; Gardner 1998). Also with respect to the choice of variables selected for analysis one needs to be cautious. It is often assumed that more parsimonious explanations exist when proposed causal factors work at the same spatial scale as the observed land use changes. Turner (1999) calls this scaling parsimony.

Often, an accepted reason for excluding a locally important factor from a regional analysis is that the local variations caused by the factor are distributed such that their aggregate effect on regional land use is small. Due to data limitation problems, rigorous application of this averaging rationale is rare. Therefore, many social factors are viewed *a priori* as ‘locally specific’ and excluded from consideration. The problem is, however, that the method used to choose ‘regionally relevant’ variables is rarely described, and local studies conducted within the region are rarely referenced. The regional or local slices through the causal web over multiple scales are derived not from an inherent spatial-scaling law of society but from an analyst’s choice, which is socially constituted. Based on his findings in the Sahelian region, Turner (1999) argues against *a* *priori* categorisation of certain types of social change as ‘local’, and therefore their exclusion by scaling parsimony from consideration as causal agents in regional analyses of land use change. In his study he shows that gender relations in rural Africa, often labeled as ‘locally specific’ have important regional consequences for changes in the composition of the livestock population, while changes in price or livestock productivity, often classified as regional important variables, have a limited importance. This brings us to the insight that single-scale approaches do not suffice to obtain a good understanding of land use change.

Researchers in the field of land use studies share the formidable task of coming to grips with the complex causal web linking social and biophysical processes (Turner 1997). For the analysis of multi-scale dynamics of complex systems it is needed to develop new methodologies. The next section describes research approaches for land use change as they have been developed by different disciplines and provides ideas of how these approaches can incorporate multiple spatial scales and levels of organisation in order to bridge the gab between these approaches.

Micro-Level Analysis

For social scientists behaviour is the central topic of study. Social science disciplines and subdisciplines have their preferred levels of analysis and often do not communicate across those levels. For instance, psychologists and sociocultural anthropologists tend to work with individuals and small groups; while sociologists tend to specialize in one level of analysis or another, from individuals to small groups to communities. Farming systems analysis is a form of micro-level land use research since it focuses on the single farmer and his/her decisions.

This micro-level focus has a major drawback for the analysis of land use dynamics. Focusing on one level of analysis, e.g. the individual, is fine, so long as we do not make assumptions or inferences about the other levels of analysis. Unfortunately, assumptions and inferences about other levels are often made, either explicitly or implicitly (Watson 1978). There are substantive reasons why theories obtained at different levels of analysis do not match each other. Human behaviour varies with group size. This is clear from the literature in sociology and social psychology. For example, groups of people will make riskier decisions than individuals; social conformity increases with group size; and inhibitions decrease with group size. In most social studies, we seem to assume that human behaviour is constant regardless of group size. In this sense this type of research is reductionist in viewpoint, claiming that individual preferences, decisions, and actions are the fundamental units through which large scale patterns and processes must be explained. By focusing on one level we restrict our power to comprehend: partial analysis may significantly decrease an understanding of the interconnections and subtle interrelations among components.

Another characteristic is that social science is generally more concerned with why things happen than where they happen. Even areas of social science in which one might expect a spatial orientation are curiously a-spatial. Relatively few social scientists outside the field of geography value the importance of spatial explicitness, nor do the typical social science data sets contain the geographic co-ordinates that would facilitate linking social science data and remotely sensed or other geographic data (Rindfuss *et al.* 1998). The lack of a spatial perspective in micro-studies ignores the context of the studied behaviour. People live their lives in contexts, and the nature of those contexts structures the way they live (Fotheringham 2000) while at the same time behaviour influences the spatial configuration of this context. When the individual is the unit of analysis, the individual's household is also a context, as well as the community, the biophysical environment and the political powers to which the individual might be subjected. Contexts can provide advantages or produce constraints. Hypotheses from theories of context may involve additive effects or interactive effects - but in either event, the hypotheses concern the effects of context on individuals or households (Rindfuss *et al.* 1998). New theories linking individual behaviour to collective behaviour are being developed to deal with scaling issues in the social sciences and explain emergent (macro) phenomena. Such a meso-level study typically studies how individual people interact to form groups and organise collective action, and how such collective decisions vary with group size, collective social capital, and so on. Game theories are often an important source for explanations at the meso-level. Strongly related to land use are well-known studies such as those of (Ostrom 1990), that focus on common property management.

At the same time a couple of new research projects attempt to link social science research with geographical data (Geoghegan *et al.* 1998; Walsh *et al.* 1999; Walker *et al.* 2000; Mertens *et al.* 2000). This type of linkage between socio-economic and geographical data can be a means to provide information on the context that shapes social phenomena.

Only this type of development can avoid that micro-analyses are carried out in a contextual vacuum and avoid that the analysis destroys the wholeness of the context by limiting the researcher's focus of attention and concept of relevance.

Macro-Level Analysis

Apart from macro-economics and qualitative studies of macro-sociology (about the centre-periphery hypothesis, global governance, the 'end of history' etc.), the social sciences are not well-developed at the macro level of human organisation. Due to its roots in physical science and system-oriented ecology, however, land use science has often adopted the macro-level approach as its natural style of thinking. Usually, this approach aims to unravel the processes that have caused land use change based on the statistical analysis of observed patterns of land use, relating these to changes in macro-level variables such as population density, tenure systems, agricultural prices and so on (e.g. de Koning *et al.* 1998; Mertens *et al.* 1997; Liu *et al.* 1993).

If macro-level analysis is carried out at the macro-scale (which is often although not necessarily the case), it is able to reveal processes that work on that scale primarily, such as a possible large-scale patterning of intensive/extensive/extractive land use zones around urban centres *(e.g.,* de Groot 1999 22). Macro-level analysis at the macro scale also appears to be a useful exploratory approach. By working high up in the cone of spatial resolution, macro-scale studies may be used as a lens or filter to focus on areas and driving factors that may require more attention, e.g. through identifying the bounds of a complex system and subdivide it into more tractable components.

In macro-scale analysis, the measurement of relevant variables is often problematic, in practice. Migration, for instance, may be partly explained by the spatial distribution of economic opportunities. The more valid variable, however, is the perception of these opportunities by potential migrants, mixed with the degree of perceived risk at the potential place of destination which, in its turn, partly depends on the degree to which family of ethnic group members are already settled at that place. Such data are usually outside the reach of macro-scale studies. Note, however, that this problem is not intrinsic. Theoretically, it is perfectly possible to connect the macro-scale maps of opportunities with an individual-level (micro-level) model of migration decision-making, in which such factors are incorporated (*e.g.,* de Groot & Kamminga 1995 224).

Because macro-level approaches most commonly use statistical correlation techniques as their primary tool to quantify the relationships between land use change and assumed driving factors, they intrinsically suffer from the general weakness of all statistical approaches, namely, the inability to establish causality. Different processes may produce the same pattern, and the same process can produce different patterns. Sometimes, even the causal direction remains unclear. For instance, does high population density cause low forest cover, or does recently cleared forest cause a high density of people filling in the empty space?

Integration: Multi-Scale Analysis

Both the micro-level and macro-level analysis paradigm have their specific strengths and weaknesses. Both approaches can be greatly improved by including multiple scales within the approach. To achieve this we should abandon our natural tendency to associate macro-scale studies with macro levels of organisation, and of micro-scale studies with micro levels of organisation. We are used to associating the concept of ecosystem with something big like a forest or a lake, and we continue to think that macro-economics is something for large-scale entities such as nations, only. We can, however, study the ecosystem around a root tip in the soil, just as we can study the macro-economics of a small town. And reversibly, we can study the individual ('aut-')ecology of the tree that is much larger than its root tip, just as we can study the micro-economics of a multinational corporation. This implies that both micro-level and macro-level studies can be multi-scale.

To start out, we may imagine a model structure that is micro-level throughout. In other words, it is composed of decision-making actors throughout. Being multi-scale, some of these actors will be farmers, others will be national agencies, and others may be global players, and all will be causally interconnected. For their decision-making, all actors will look at the variables that concern them on their own level, such as total farm income, soil types distribution at the farm level, local culture, national food production, national pride, national distribution of population and forest; global relative competitiveness, global biodiversity hotspots, and so on. Many of these variables are spatial, thus, all actors can be accompanied by the maps that regard them at their level and shape the context of the actors. All the while, such an approach remains (multi-)micro, hence causally strong but never able to explain the emergent system-level (macro) variables, such as prices or forest distribution, that it uses to model the decisions of the actors.

Second, we may imagine a model structure that has its origin in macro-level approaches through studying the spatial patterns of land use with the help of GIS and/or remote sensing and relating these patterns to (proximate) variables that represent aggregate processes seen as driving forces. Being multi-scale, the extent and resolution of analysis are varied from very coarse all the way down to, say, the extreme of one pixel representing approximately one farm. The statistical analysis connecting observed land use to assumed driving factors may then be run at all these scales, from the village (multi-farm) scale upwards, each scale connected to its own hypotheses and theories. This approach is central to the spatial analysis that is part of the CLUE modeling framework (Veldkamp and Fresco 1997; de Koning *et al.* 1999; Verburg and Chen 2000).

In this approach, each spatial scale may also be connected to its own micro-level auxiliary models, as indicated already in the migration example. The basic step is to identify the actors that have the particular map 'in their head' as a co-determinant of their decisions. At a national scale, for instance, the agricultural agency planning the optimum distribution of crop types is an example, as is the prospective migrant using another national-level map, and the logging corporation using yet another. That way, the 'column' of multi-scale maps becomes covered with actor models like a Christmas tree, each actor model replacing a statistical relationship by a set of essentially testable causal assumptions.

Finally, it may be noted that the two approaches – micro-level multi-scale analysis and macro-level multi-scale analysis - begin to interweave. This indicates that steps towards a consistent construction of the two multi-scale approaches are steps on a progressive road and that the micro-level and macro-level approach, originating from different disciplines, may truly complement each other.

The Puzzle of Land *Use* Harmonization Between Levels

The different approaches for land use change research described here recall differences in world view that underlie how people explain the functioning of complex systems. A more integrated approach, blending processes and structures at several scales and including their interactions, should become the norm in land use change research. Such an approach should recognise land use dynamics derived from the interaction of processes and structures at scales ranging from the individual tree to the patch, region, and even globe. A pluralism of emphases, from individual-based to regional/global models will continue to be useful for addressing problems at multiple scales, with meta-modeling used when linkage is needed (Baker *et al.* 1999). To achieve this is a true challenge and requires researchers to step beyond their disciplinary traditions (Wilbanks *et al.* 1999). A number of approaches, e.g. the approaches developed by De Groot and Kamminga (1995) and by Veldkamp and Fresco (1996), are already available that, from their own discipline try to move beyond the disciplinary boundaries and traditional rigid levels of analysis. These developments will not only benefit our understanding of the land use system itself but also add to the study of other complex interdisciplinary systems as well.

3.3 Scaling Land Management Information – A Case in Point

Passing information concerning human driving forces and processes of change through a hierarchical land use classification schema is one of the most pressing needs for harmonization. Those who develop small-scale LUCC models request that large-scale studies scale up both land use categories and the principal forces compelling human uses and their change. Three principal problems accompany this task: i) different processes operate at different scales; ii) cultural and social context defies quantification and systematic scaling; and iii) aggregated variables at smaller scales do not necessarily accurately represent individuals at larger scales. This case illustrates the latter problem.

The study, located in the Andapa region of Northeast Madagascar, categorized farm units, villages and the region as a whole by the trajectory of agricultural change that best characterized the change in management strategies operating on those landscapes. The trajectories were then correlated with land covers and their change. If the data gathered from this study were to be recorded within a land use classification schema for LUCC, a likely piece of information to accompany land-use categories might include the trajectory of agricultural change occurring in that landscape.

Two procedural scenarios might be followed to identify and represent land-use categories and change trajectories at smaller scales: i) interpret indicator variables at large scales to classify land use categories and change trajectories, and then aggregate these categories to a smaller scale; or ii) aggregate the indicator variables and then classify land use categories and change trajectories at the smaller scale.

This study finds that these two procedures would produce entirely different results. The study identified dominant trajectories of change at the regional scale following both procedures. In the case of the first procedure, the study classified each farm unit by change trajectory, and then identified the dominant trajectory as the one followed by most farm units in the region. The result did not match the dominant trajectory found using the second procedure. Misregistration occurred because during the aggregation process in the second procedure, processes operating at the larger scale cancelled each other out. To illustrate, 55% of farmers may increase output by increasing the amount of land in cultivation and reducing fallow cycles (*intensification through excessive cropping frequency*). The other 45% may choose to increase output by weeding more frequently on smaller fields, thereby decreasing the amount of land in cultivation (*non-innovative intensification*). When operating in the same landscape, and when analyzed at a smaller scale, the combined effect looks like most farmers did not change the amount of land area in cultivation at all (*no change*). In other words, the first procedure would identify *intensification through excessive cropping frequency* and the second procedure would identify *no change* as dominant.

The problem illustrated in this case is just one manifestation of a larger problem identified as the modifiable area unit problem. The implication of the modifiable area unit problem for a land use classification system is critical. Until there is a solution to this problem, it may be impossible to identify a procedure for passing information concerning human driving forces and processes of change through a hierarchical land use classification schema.

4. The Opportunity

The Meeting in the Middle Workshop was convened at a propitious moment in the development of the science of land use and cover change. First, land cover mapping is quickly approaching a sort of convergence, as reliable global products at ever-finer spatial resolutions become available, and high spatial resolution efforts cover increasingly large parts of the globe. In addition, the Food and Agricultural Organization has just released a software implementation of a universal land cover classification scheme resulting from a decade of consultation with a wide range of collaborators. This section briefly examines recent progress in global land cover mapping, then presents the FAO Land Cover Classification System (LCCS) in some detail, and concludes with the evaluation of the LCCS by the workshop participants.

4.1 Recent Advances in Global Land Cover Mapping

The past few years have seen significant progress in the development of global land cover and related databases. Several regional and global views of land cover (especially forest cover) have been generated from data acquired by the Advanced Very High Resolution Radiometer (AVHRR) instrument carried by NOAA satellites at the coarse Global Area Coverage (GAC) resolution of 8 km (DeFries *et al.* 2000). In recent years, products have become available at the higher Local Area Coverage (LAC) resolution of one kilometer, including the international Global Observation of Forest Cover project (Hansen *et al* 2000).

Another product using this data was completed in 1999 under the aegis of the International Geosphere-Biosphere Programme's (IGBP) Data and Information System (DIS), in collaboration with a broad consortium (Belward *et al.* 1999; Loveland *et al.* 2000). The availability of improved 1 kilometer resolution data from the SPOT VEGETATION instrument has spurred another effort, known as Global Land Cover 2000 (see Plate 7). Likewise, the 250 meter data from the Moderate Resolution Imaging Spectrometer (MODIS) instrument promises global land cover products of ever-increasing spatial and classification specificity. A review of these efforts can be found in a special issue of the International Journal of Remote Sensing (Vol. 21 Nos. 6 & 7, 15 April 2000).

Other related global databases at similar spatial resolutions are becoming available concerning, for example, the incidence of fire (Stroppiana *et al.* 2000) and human population density (Dobson *et al.*

2000; CEISIN n.d.). In addition, several regional and (sub)continental efforts have achieved reliable views of land cover from high resolution imagery (LandSat, SPOT XS, etc.), including the U.S. Geological Survey's Multi-Resolution Land Characteristics (MRLC) Database of North America, the European Environment Agency's CORINE land cover database, and FAO's Africover. Such intermediate scale products may bridge the gap between the global coverages noted above and local case studies using aerial photography and/or one or more scene of high resolution (Landsat, SPOT, etc) imagery.

This near convergence in spatial resolution between local information and global coverages raises the issue of land use and cover harmonization to an operational necessity.

4.2 Progress in the Harmonization of Land *Cover* Classification

The Land Cover Classification System (see Plate 1) and its software program is a comprehensive standardized a-priori classification system designed to be able to meet specific use requirements, and created for mapping exercises, independent of the scale or means used to map; any identified land cover anywhere in the world can be readily accommodated. The proposed classification uses a set of well-defined independent diagnostic criteria that allow correlation with existing classifications and/or legends. Therefore, this system could serve as a basis for a universal reference system.

Historical Background

The AFRICOVER initiative on the definition of a Land Cover Classification was initiated during the expert consultation held in Addis Ababa, in July 1994. The Working Group on Classification and Legend had the task to define a standardized classification, which could be used for mapping land cover in all African countries. This classification had to meet the following requirements:

- be applicable for the interpretation of satellite imagery and aerial photography;
- be oriented to the preparation of multi-user databases;
- be compatible with existing classifications/legends in Africa;
- be practical and adapted to existing African capacities; and
- liaise with ongoing initiatives on the classification and definition of land cover and land use.

Following this expert consultation, a user definition study was undertaken in 27 African countries to evaluate the information requirements and the priority classes to be mapped within the project. The latter survey clearly indicated the importance of cultivated cover types. This survey also included an extensive view of existing maps and databases on land cover and land use existing in Africa.

At a meeting in Rome in 1995, the approach of AFRICOVER was merged with the parallel efforts of the United Nations Food and Agricultural Organization (FAO), the United Nations Environment Programme's World Conservation Monitoring Centre (UNEP WCMC), the Institute for Terrestrial Ecology (ITE), and the International Institute for Aerospace Survey and Earth Science (ITC). Several papers and preliminary reports were prepared in which existing classifications and/or legends as well as nomenclatures were analysed (Negre 1995). This resulted in the development of the concepts for the AFRICOVER Land Cover Classification Scheme which were discussed and approved at an international working group meeting in Dakar in 1996 (Di Gregorio & Jansen 1996).

The AFRICOVER Project, and potentially it's successor – ASIACOVER –discussed and endorsed at the Ministerial Meeting in Delhi for Science and Technology in November 1999, have taken the lead in developing approaches for concepts, definition and classification of land cover and land use. The overall objective of this initiative is to answer the need for standardisation and to develop a common integrated approach to all aspects of land use and land cover. This implies a methodology which is applicable at any scale, and which is comprehensive in the sense that any identified land cover or land use anywhere in the world can be readily accommodated.

The FAO East Africa Project, which covers 11 (and potentially 12) countries in its first two phases, has already been extended to include 6 countries in the Congo Basin and now geographically covers over half of the African continent. In so doing the capital costs of data acquisition and processing as well as stratification will be provided to the participating countries as a viable and cost effective basis for development of an area frame. The first operational module of Africover - East Africa is responsible for the development of the operational software - the Land Cover Classification Software. At present the first full operational version of the classification (adopted at the international meeting in Dakar in July

1996) and its software program has just been released in time for the Meeting in the Middle Workshop – October 2000.

Similar efforts are now being considered for the development of an *a priori* land use classification system. The application of LCCS in the mapping domain will be accomplished through new operational tools such as AIMS, a software tool which transforms the classification into the mapping domain.

Objectives and Potential Utility of the LCCS

The main objective of the initiative for definition of a reference classification is to respond to the need for standardization (or harmonized collection of data, as mentioned in the United Nations Conference on Environment and Development's Agenda 21 Chapter 10, for which FAO is Task Manager within the UN system) and to develop a common integrated approach to all aspects of land cover. This implies a methodology that is applicable at any scale, and which is comprehensive in the sense that any land cover identified anywhere in the world can be readily accommodated.

The approach developed for land cover could serve as the basis for a reference classification system with links to specific expertise, because it describes and allows correlation of land cover with a set of independent diagnostic criteria, the so-called classifiers, rather than being nomenclature based. Also, existing classifications and legends can be "translated" into the reference system, thus facilitating the use of existing historical materials. Re-arrangement of the classes, based on re-grouping of the used classifiers, facilitates the extensive use of the outputs by a wide variety of end-users.

The main objective is the development of a worldwide methodological approach and relevant tools for land cover classification and mapping, that could serve as a worldwide land cover reference basis. More in details, the aim is to:

- respond to the need for land cover data of a variety of end-users;
- apply the methodology in mapping exercises, independent of the means used, which may range from high resolution satellite imagery to aerial photography;
- link with existing classifications and legends, allowing comparison and correlation;
- support international ongoing initiatives on classification and

definition of land cover; and

- harmonize principles and methodology for land cover mapping.

This international standard will be applied to other modules of AFRICOVER at regional and national levels in Africa, and are already in use in several other country programs outside of Africa, e.g. Afghanistan, Azerbaijan, Bulgaria, Lebanon and Yemen, and are being considered for inclusion in the forthcoming Asiacover project.

The utilization of this new worldwide common language of land cover between different countries and different type of final users, in support to the development of a reliable environmental baseline information source, will lead to a basic source of detailed and homogeneous environmental information as baseline for more complex systems. The resulting land cover data set will be able to supply a large amount of detailed, homogeneous and standardized information for a wide range of applications. The homogeneity of the data will allow an immediate, scientifically sound and economic replicability of each application at a national, regional and international level.

Technical Specifications of LCCS

Land cover classes are defined by the combination of a set of independent diagnostic criteria, the so-called classifiers, which are hierarchically arranged to assure a high degree of geographical accuracy (also referred to as "mapability"). Because of the heterogeneity of land cover, the same set of classifiers cannot be used to define all land cover types. The hierarchical structure may also differ from one land cover type to another. Therefore, the classification is designed according to two main phases:

(1) an upper, dichotomous, phase where eight major land cover types are distinguished;

(2) a lower, modular-hierarchical, phase where the set of classifiers and their hierarchical arrangement are specific to the major land cover type.

This allows the use of the most appropriate classifiers and reduces the total number of impractical combinations of classifiers. Because of the complexity of the classification and the need for standardization, a software program of which the beta version has been developed, assists the interpretation process: it reduces heterogeneity between interpreters, and with interpretations over time. Because of the flexible manner in which the classification is set up (creation of classes at different levels of the system and the optional use of modifiers and/or environmental and/or specific technical attributes) and the tremendous number of classes possible, this innovative software program assists the user by selecting the right class going stepwise classifier by classifier. This software will be integrated into a digital image interpretation software which will allow interpretation of imagery followed by labeling of the mapping units with the land cover classes. The classification system provides a mutually exclusive Land Cover Class which comprises: (1) a unique Boolean formula (a coded string of the classifiers used); (2) name/nomenclature; and (3) a unique numerical code. Both the numerical code and nomenclature can be used to build an automatically generated Legend with the created classes grouped according to the main land cover categories and their level of detail. The nomenclature can be linked to a user-defined name.

Further definition of the Land Cover Class can be achieved by adding attributes. Two types of attributes, which form separate levels in the classification, are distinguished:

- Environmental attributes: these attributes (e.g. climate, landform, geology) influence land cover but are not inherent features of it and should not be mixed with "pure" classifiers.
- Specific technical attributes: these attributes refer to the technical discipline. As an example, for (Semi-)Natural Vegetation floristic can be added (the method how this information was compiled and a list of occurring species), for Cultivated Areas the crop types can be added according to broad categories commonly used in statistics or at the detailed level of species.

This program will include the following modules:

- Classification: land cover classes are defined by the combination of a set of independent classifiers, which are hierarchically arranged and which can be linked with environmental and specific technical attributes.
- Legend: storage of the defined classes according to the domains to which the classes belong. This module facilitates the exporting of data via commonly used file formats.
- Field Data Entry: storage of the detailed field survey information and automated classification of the data. Retrieval and edit functions exist.

- Translator Tool: comparison and correlation of classifications and/or legend through the reference classification.

Advantages

In order to homogenize and take into account the different nomenclature/legends existing in the different Countries, AFRICOVER East Africa will be the first project to use the FAO Land Cover Classification System and the related software.

From a conceptual point of view, the advantages of the proposed classification are:

- A real classification system in the sense that it covers all possible combinations of classifiers. Some combinations are excluded due to some conditions, which are elements of the classification system.
- A given land cover class is clearly defined by a set of independent classifiers. The classifiers are clearly differentiated in: pure land cover classifiers, environmental and other classifiers and discipline specific classifiers. This avoids an unclear mixture.
- The classification is truly hierarchical. The difference between a land cover class and a further sub-division of this class is given through the addition of new classifiers. The more classifiers used, the greater the detail of the defined land cover class.
- The classification can be used as reference classification system. In fact, the emphasis given to the set of classifiers defining the class allows easy correlation between existing classification/legend and the proposed one.
- The specific design of the classification allows incorporation into GIS and databases. The pure land cover classes can be used in overlay procedures to make combinations with *e.g.*, climate and physiography, to create new classes.

From a practical point of view:

- The classification is designed for mapping. The hierarchical arrangement of classifiers is set up to assure a high level and precise mapping accuracy (clear definition of boundary between two land cover classes).
- It facilitates the integration of different types of data.
- It rationalizes the field data collection. As the classes are defined

by a combination of classifiers, field surveyors should detect the single classifiers and not deal with the final class name. This means that the field survey can be done independent of, or parallel to, the interpretation process.

- It is highly flexible, responding to the information available or gathered in a given area or for the time and budgetary constraints of a project. This means that within one land cover map, the mapping units will contain the maximum available information but this quantity of information may differ between mapping units. This will not affect the homogeneity of the resulting map.
- It facilitates the standardization of the interpretation process contributing to its homogeneity. In fact, the interpreter is not dealing with a final class name but is dealing with one classifier at the time. This reduces heterogeneity between interpreters and with interpretations over time.
- It is multi-user oriented. Because the class is defined by a set of classifiers, every user can make a re-selection based upon the classifier(s) of interest.
- It is designed to map at a variety of scales, from small to large-scale.

Validation and distribution

This product, developed as part of the normative process, will be the subject of peer review by a panel of internationally recognized high-level experts, in order to promote its worldwide application. The organizations involved in the validation of LCCS are:

- the Global Land Cover 2000 Project (GLC 2000) - Joint Research Center (JRC) Ispra, Italy;
- the United Nations Environment Program (UNEP);
- the U.S. Federal Geographic Data Committee (FGDC); and
- the Global Land Use Cover Classification (GLUCC) working group of the International Geosphere-Biosphere Programme (IGBP).

4.3 An Assessment of the Utility of the LCCS for Land Use and Cover Change Studies

Several of the workshop participants assessed the degree to which the Land Cover Classification System enabled the recording of the kinds of information they might typically use in local or regional land use and cover change studies. This section reports the results of these assessments, and presents a list of suggested modifications to the software.

Land Use Survey & Agricultural Census Data: Indonesia (See Plate 2)

Studies on land cover and land use change often rely upon data gathered by either remote sensing or household studies, depending on the extent of analysis and the purpose of the specific study. Household studies are generally difficult to reference to the spatial distribution of land use changes and do not always cover the entire area of study. Land cover and land use information derived from the interpretation of remote sensing images can provide us with detailed information of the pattern of land cover/use. The information derived from the images normally only allows us a snap-shot of the land use situation, without being able to relate this to the cropping sequence, land management procedures and land use change driving factors. These are all of interest to the understanding of the processes that cause the observed pattern of land use to change.

Land use survey data and/or agricultural census data provide an intermediate data source that might help us to relate household survey information to the spatial information derived from remote sensing images. Besides information on the spatial extent of different land cover and land use types within a certain area this type of data most commonly supplies information on land use management variables, *e.g.*, yields, fertilizer and irrigation management, and labour input.

Census and agricultural survey data often have the following characteristics:

- Focus on agriculture: Census data are generally gathered as a large undertaking of the national statistical office of the central government as a means to inform the government on the performance of the various economic sectors and to facilitate planning. Therefore, land-use relevant surveys have a focus on agricultural production and generally contain only limited information on the extent and distribution of natural ecosystems.
- Organised by administrative units: Census data are generally

organised by administrative units following the hierarchical subdivision of the administrative system in the country under consideration, *e.g.*, province, district, sub-district, and village. By combining the agricultural survey reports with maps delineating the extent of the administrative units it is possible to convert the data into maps that are useful for land use change research.

- More land use types within one spatial unit: Because census surveys commonly report land use types by the area found within the administrative unit there are more land use types reported within the same spatial unit. Therefore, it is common to represent land use by a continuous representation indicating the relative coverage of each land use type within a spatial unit. For example, 30% of a district can be covered by grassland whereas forest and agriculture respectively use 50 and 20%. This data representation is different from the data representation obtained by remote sensing interpretations and has consequences for the analysis of the data.
- Fixed temporal resolution: The temporal resolution of the data is bound to the frequency of the census survey. In many countries census surveys are made once every 10 years while in some countries yearly updates are provided. For most land use studies such a 10-year frequency is relevant for analysing changes.
- Fixed classification: The census bureau fixes the land use classification. Documentation of the classification criteria is often poor. Problems with the interpretation occur when the classification system is changed between two census surveys.
- Inaccuracies: Census data are subject to inaccuracies due to reportage problems and/or problems related to the specific situation in the country considered. A well-known example is the under reporting of cultivated area in China. Due to linkages of the statistical system and the tax system land users were eager to report less land than they were actually cultivating. Recent surveys indicate that under reporting might amount to greater than 40% (Smil 1999).

Classification issues

In order to be able to link census-based studies to land cover change analysis by either remote sensing and/or household survey it is essential to use a common classification for land cover. The FAO Land Cover Classification System is a potential candidate for such a system.

The census data can be classified by LCCS by translating the class definitions given in the census reports. Often times a major constraint is the limited documentation given by the census bureau on the exact classification criteria. Table 2 gives an example of the translation of several of the classes of the Indonesian land survey into the LCCS. Because of the hierarchical organisation of the LCCS it is necessary to create a mixed class that both incorporates single and multiple cropping, as no specification is given in the Indonesian land survey concerning the cropping system. The spatial aspects of the land cover class are defined as continuous due to the limitations of the LCCS in dealing with unknown spatial aspects, which is common in census data (in contrast to remote sensing data).

The LCCS offers the possibility to provide a better documentation of the land use/cover classes within the census system. To allow comparability between data sources and between different census surveys (between survey years and countries) it would benefit land use research if statistical organisations used classification schemes similar to LCCS in order to provide the user with all relevant information of the land cover/use class.

Local-Level Agricultural Change: Madagascar (See Plate 3)

Two kinds of studies were represented at the Meeting in the Middle workshop that demand different kinds of information storage from a cover classification schema. One set develops parcel-level spatially-explicit models of landscape change, requiring a classification scheme that encompasses a host of attributes, such as soils, vegetative biomass and slope, that are believed to factor into farmer decisions to cultivate a parcel with a particular crop at a particular time. Another set develops village-level models that are spatially-explicit but at a higher level of abstraction, and thus do not require the same degree of detail on a parcel by parcel basis. The challenge is to ensure that a cover classification schema, such as LCCS, suits both types of studies, and facilitates comparative analysis.

This case represents village-level cover change studies. In the Andapa region of Northeast Madagascar, land tenure institutions operate at the extended-family and village levels, making it impossible to directly associate particular farmers with particular parcels over time. Thus, this study does not attempt to model cover changes on particular parcels, but associates trajectories of agricultural change and land-cover change at the extended family, village and regional levels.

The region practices a mixed-cropping system that includes hill rice in a bush-fallow system (called “tavy”), irrigated paddy rice, and coffee and vanilla as market crops. To assess change in this cropping system, the study utilizes a typology of “change trajectories” developed by the induced-intensification thesis within the agricultural change literature (Brookfield 1984; Hyami and Ruttan 1985; Turner and Ali 1996). It then empirically identifies the land-cover changes associated with each change trajectory. For example, the literature defines *intensification through excessive cropping frequency* as increasing cropping intensity without adding any other inputs, such as labor. Associated cover changes in the Andapa region might include an increase in land area in hill rice cultivation, a decline in older fallow fields, and an increase in younger fallow fields. As another example, *innovative intensification* is defined as a shift in techno-managerial level within a management system. An associated cover change might be a conversion of fallow fields into irrigated paddy rice. In total, this study associates land-cover changes with eight change trajectories.

To track the cover changes associated with each trajectory, seven land-cover categories were chosen: forest, hill rice in cultivation, single-cropped irrigated rice, double-cropped irrigated rice, permanent tree crops (coffee or vanilla), young fallow fields (aged one to 4 years), and long fallow fields (aged five years or more). The choice to classify fallows by age is controversial. It is generally recognized that farmers manage their fallows by many other criteria besides just age (Gleave 1996). Thus, age alone is not useful for those studies developing parcel-level spatially explicit models. Nevertheless, cropping intensities derived from fallow ages are commonly used in the agricultural change literature because, at the village and regional levels, cropping intensity is adequate to identify significant shifts in levels of intensification, such as from shifting fallow to bush fallow to permanent cropping systems.

Translating these cover categories into LCCS were largely successful. The forest, irrigated rice (single and double cropping), and permanent market-crop categories fit easily and mutually exclusively within the hierarchical system. Fallow ages and land in hill-rice cultivation did not, however, fit within mutually exclusive categories in the system. The LCCS hierarchical scheme offers two classification categories for all land managed in a swidden system. Land may be classified as either shifting-fallow (where fallows are cultivated on a 1:4 cycle) or bush-fallow (1:5 or greater). In such a scheme, all parcels, whether they be in cultivation or in any age of fallow, are classified into one of those two categories. This system does not allow this study to retain unique cover categories for hill-rice cultivation and different aged fallows which are critical cover categories for monitoring the cover consequences of *intensification through excessive cropping frequency* and other change trajectories. Thus, during the Workshop, an alteration in LCCS was discussed, where land in cultivation and land in fallow would remain in mutually exclusive cover categories, and where the user could define the threshold at which fallow ages would be differentiated.

It remains a point in question, however, whether those who develop parcel-level spatially explicit models would wish to operate within a classifications system where fallow ages rest highest in the hierarchical structure. All other attributes that factor into farmer decisions to cultivate a particular parcel, such as slope and vegetative biomass, would have to lie lower in the hierarchical structure. If, on the other hand, some other attribute is chosen for the higher position in the hierarchical structure, those studies that choose to track only fallows must be allowed to "skip" that higher level. Questions of comparability between studies may then ensue.

Floodplain Forest Management: Amazonia (see Plate 4)

Caboclo populations' management of floodplain forests of the Amazon estuary leads to the creation of the so-called Açaí Palm forest (Euterpe oleracea mart.), a structurally similar, but economically and floristically different land cover than floodplain forest. While managed forest class (Açaí Palm forest) represents the most important land use system in the regional floodplain environment (in economic, nutritional, and area extent terms), it has been overlooked as an important economic activity, as well as an deforestation alternative due to lack of characterization of this land cover class at the regional level and misunderstanding of managed forests not as an extractivist, but as a production system. The integration of vegetation inventory, land use history interviews, and Landsat TM images allow discrimination of these classes and also classes of secondary vegetation needed to the study of agricultural intensification. Classification systems are constructed based image analysis and vegetation inventories for various areas of managed and unmanaged forests.

This production system poses a challenge for land use analysis in the region. Whereas most land use intensification studies focuses on change in forest cover (e.g., rates of deforestation and cycles of fallow management), in this case we observe a conversion in forest cover based on change in species composition. However, conversion of floodplain forest to Acai palm forest does not change significantly key indicators of forest structure (e.g., density, basal area, canopy height), but the relative contribution of different species to its structural components. In intensively managed areas, canopy architecture (e.g., absence of emergent trees, roughness) provides enough changes to allow spectral discrimination (for instance in Landsat TM data) from unmanaged forests. On the other hand, output fruit production (the second most important caloric source to a significant regional population) may increase up to ten-fold (likewise in economic return). In practical terms, classifying these managed forests as a distinctive land use class (and mapped as a separate land cover) helps to recognize an intensive production system, commonly seeing as extractivist.

LCCS, as a land cover translation tool, proved useful in maintaining this class as distinctive from surrounding unmanaged forests. In this sense, it helps to re-define indicators of land use intensification beyond land cover change, but including conversions that maintain land cover structure, while changing internal species composition. Therefore, this classification system, while not substituting locally-specific classification keys and nomenclature, opens possibilities to present it as an important land use class that is dominant, but most often “invisible” in the Amazon estuary – and highlight the role of local producers in the regional economy.

Sketch Maps & Multi-Spectral Imagery: Mexico (See Plate 5)

The Southern Yucatan Peninsular Region (SYPR) project seeks to explain, model and project the land changes underway in the region and their implications for the forests through integrated research that joins ecological, social and remote sensing sciences. It aims to provide understanding of the dynamics of deforestation by means of spatially explicit assessments and models that can be used to monitor and predict changes in forest cover under different assumptions. The improvement of multi-spectral imagery classification through land use history research using sketch maps and a spatially explicit characterization of land history are results of the integration of the remote sensing and social research. Data from interviews with small-holders in the SYPR, and sketch maps of the land-use history of each respondent's parcel are linked to Thematic Mapper (TM) imagery with the use of global positioning system. The creation of sketch maps directly involves the participation of land managers who document past and current land conditions and uses. Plots were located using GPS allowing the association of sketched maps with the imagery and the development of training sites important in the process of classification. At the regional level, six main land cover classes characterize SYPR: wetland forest, upland forest, agriculture, successional growth (shrub/arboreus dominated), seasonal inundated savannas and bracken fern (*Pteridium aquilinum*)

An exercise with LCCS to standardize SYPR legend provides straightforward results. The main land-cover types found in SYPR were translated with LCCS without difficulties. LCCS allows the characterization of structure and composition of different land covers. Characterization as such makes the use of a hierarchical system such as LCCS very useful, enriching the original legend with the addition of environmental attributes such climate, soils and landforms, which are usually dismissed in common classification schemes.

Difficulties with LCCS might take place when translating land covers linked to agricultural practices and fallow cycles as explained in the Madagascar case. For SYPR biophysical characteristics of the crops and the different stages of secondary growth were appropriate for a direct translation. Agricultural practices in SYPR are characterized by slash and burn agriculture dominated by maize and usually intercropped with squash and beans, and LCCS provides an easy translation for cultivated areas with mixed crops. Secondary succession falls into the semi-natural terrestrial vegetation, which implies land being used and allows the characterization of life forms and stratification. In general the translation of SYPR legend using LCCS was not difficult and it is useful in providing a detailed characterization of current land cover classes.

Mixed Grazing/Farming Systems: Chile (See Plate 6)

This research project is aimed at identifying the ways in which biophysical, socio-political and economic variables affect a) the vulnerability of the rural population to climatic variations and b) the land-use in the semi-arid region of Chile. The study area is a section of the Limarí River basin where the average annual rainfall is 162 mm. Here, land is either privately or communally owned. Those who inhabit communal lands are considered among the poorest in the country. Some of the project findings indicate that these households have restricted and unequal access to resources such as irrigated land, drinking water, credit, education, and health care. Their livelihood systems have depended upon low-yield rainfed agriculture—mainly wheat—and goat herding, both of which have had great impact on the soil and the natural vegetation due to the lack of sound managerial practices. On the other hand, land and water are in high demand by private investors due to the favorable climatic conditions of the area. Table grape and wine productions have increased at a fast rate during the last decades, expanding agriculture onto more marginal soils. Thus, both communal and private lands have been subject to long term human-driven pressure, resulting in significant land-use change.

Land-use change is being assessed utilizing Landsat TM imagery acquired during two rainy years--1987, 1997--and two dry years--1986, 1998. All images were acquired during or right after the rainy season. The Soil Adjusted Vegetation Index (SAVI) was calculated for each scene to map relative greenness of the land cover. To assess change, the difference between the 1987 and 1997 image pair and the 1986 and 1998 image pair was derived subtracting one SAVI image from the other. Based upon the distribution of the difference values thresholds were established at the mean plus-or-minus one standard deviation. Pixels exceeding this threshold were identified and through use of a 7x7 majority filter, only areas exceeding 270 square meters were retained in the final change map for the dry and the wet years. These areas were examined using 1:20,000 scale aerial photography and field verification visits to label the nature of the change present in each area of change.

Rugged topography and skeletal soils characterize the bulk of communal land. These lands are usually dedicated to annual crops. On the other hand, private holdings, which control almost all of the water rights, are generally located in the richer, flat valley bottomlands and are devoted to perennial crops such as vineyards. Thus, location and crop types are two of the criteria that can be used to identify property regimes. LCCS was able to capture the information emerging from the SAVI image analysis (rainfed and irrigated agriculture, riparian vegetation, and open rangelands), but didn't allow for the recording of much of the land use information. In this case study, having the possibility of combining the type of crop, its location, and the property regime would have been a great help in generating a more comprehensive legend.

Note that specifying a “scattered-clustered” spatial distribution of the fields causes LCCS automatically assume a mixed mapping unit, when the user’s intention may be to discriminate fields that lie in fallow from those actively under cultivation. This issue is treated in some detail in the recommendations, below.

Modifications to the LCCS

The workshop participants made a number of relatively minor concrete suggestions for the improvement of the LCCS software, including:

- The system should be more flexible in allowing the user to skip levels for which information is missing, in order to be able to add information at supposedly lower levels for which information is available.
- The user should be forced to stipulate the spatial and temporal scale of their observations, so that choices about, for example, the spatial configuration of the land cover are meaningful (what is scattered at one spatial scale is continuous at another, and fields may be cultivated during one period, and fallow during another).
- The temporal sequence category should be more open, in order to accommodate information about trajectories or cycles; enable recording of analyst’s notion of “original” or potential, vegetation, which would link to degree of modification; similarly, other aspects of land management besides water should be included, such as tilling, fertilization, etc.; finally, the Save/Export function is confusing (it is unclear that updates to the classification automatically change the database without prompting the user for confirmation).
- A road map allowing users to follow their progress and choices in the classification process would be useful.
- Some accommodation should be made for the inclusion of ownership, control or access information.

These suggestions were taken in a very positive light by the FAO-Africover representatives, who will attempt to insure their implementation in the next version of the software.

5. Conclusions

The workshop discussions concentrated on both theoretical and practical concerns of harmonization - the justification for, as well as the implementation of, a harmonized scheme.

1) Recent developments in earth observation and analysis make the harmonization of land use and cover information a practical necessity; at the same time a tool has just become available that promises to achieve a major part of the harmonization.

Land cover mapping is quickly approaching a sort of convergence, as reliable global products at ever-finer spatial resolutions become available, and high spatial resolution efforts cover increasingly larger parts of the globe. As the linkage of these various perspectives becomes more practical, the issue of land use and cover harmonization is raised to one of operational necessity.

The search for a standardized classification scheme for land use and land cover has a long history, and the need has been increasingly recognized over the last decade, with two United Nations agencies, UNEP/GEMS and FAO, taking the lead in organizing expert meetings to build an international coalition to develop a solution. By the time the need for harmonization was recognized in the LUCC Science Plan in 1995, the FAO-led effort had achieved good progress in developing a conceptual framework. The Meeting in the Middle Workshop coincided with the release of Version 1 of the FAO's Land Cover Classification System (LCCS) software – a software implementation of this conceptual framework. The LCCS is intended to be a universal land cover classification scheme that will enable the translation of any and all prior or future classifications into a universal framework (nomenclature/coding). In part, the Meeting in the Middle Workshop was designed to enable participants to evaluate the LCCS product, and to make appropriate recommendations to the LUCC community. Further, the Workshop was intended to make recommendations concerning future efforts

2) The full, universal, harmonization of land use and cover information is quite a difficult and perhaps impossible undertaking, which faces significant obstacles, including varied and unsufficiently specified user needs and long-standing theoretical and practical disciplinarity.

There exists a broad range of constituencies for land cover information, which have not been specified to the degree required to judge how any one classification scheme might serve these varied interests.

What has become quite evident is that distilling research findings extending across local and global research perspectives, different study areas, and for a host of space-time scales is critical to understanding how land use and land cover varied in the past, how they are organized today, and how they may vary in the future. To understand pattern is to understand form, and hence efforts at classification harmonization moves us closer to the time when we can use land use and land cover as signatures of biophysical processes as well as keys to deciphering the influence of the human dimension of landscape structure.

The different approaches for land use change research reflect differences in world view that underlie how people explain the functioning of complex systems. A more integrated approach, blending processes and structures at several scales and including their interactions, should become the norm in land use change research. Such an approach should recognise land use dynamics derived from the interaction of processes and structures at scales ranging from the individual tree to the patch, region, and even globe. A pluralism of emphases, from individual-based to regional/global models will continue to be useful for addressing problems at multiple scales, with meta-modeling used when linkage is needed. To achieve this is a true challenge and requires researchers to step beyond their disciplinary traditions.

The important aspect of linking case studies may be to integrate the understanding about process, but not necessarily to integrate land cover or land use information, *per se*.

3) The FAO Land Cover Classification System was found to be a quite useful tool based upon a well-thought-out strategy for harmonizing land *cover* classification.

In the early stages of the GEMS/FAO effort, the standardization of both land use and land cover were under consideration, but the two became separated and pursued independently. The land *use* and land *cover* efforts took distinct conceptual paths: while the land use classification effort moved towards the development of a glossary of land use descriptors, the land *cover* classification effort adopted the conceptual stance that standardization cannot be achieved in the realm of description; rather that standardization must focus on specific attributes of land covers, and strove to develop a set of classifiers that would unambiguously differentiate classes. A fundamental set of classifiers was assembled and placed in a logical (hierarchical) framework, and a protocol established for the parameterization (gradient breaks) for each of those classifiers. The resulting classification system can be used to develop legends of different degrees of specificity, but which can therefore be logically aggregated (generalized) until comparability is achieved.

4) Despite having been designed primarily to harmonize the classification of land *cover*, LCCS in fact incorporates a certain number of land use attributes, particularly concerning agricultural land management practices. Several suggestions for improving the software's capabilities in this regard were offered and received in a positive light by FAO. It was generally concluded that LCCS should not – at least in the short-term – be expanded to encompass a full range of land use attributes; perhaps a separate, but linked, system should be developed.

Land use characteristics, including management practices such as water supply control, and frequency of cultivation, are included in LCCS as environmental attributes of "cultivated and managed areas." Some problems were encountered in specifying such attributes, for example the system currently expects the user to classify fallow fields under the broad class of "primarily non-vegetated areas", while fields currently being cultivated are expected to be classified under "primarily vegetated areas". The land use researcher wants to be able to classify these lands as essentially similar – as two fields that just happen to be in different stages of the rotation at the time of classification. This speaks to broader issues of the capture of temporal information for which the LCCS has limited capabilities.

Furthermore, while it is possible for the individual user to add practically any other land use attributes desired, this must be done in an *ad hoc* fashion, resulting in incompatibility. This was judged an unacceptable long-term solution. In terms of expanding the capabilities of the LCCS to handle land *use* information, it was noted that each new classifier that is added – especially at higher levels – increases the number of possible eventual classes, and thus the complexity of the system, significantly. Furthermore, it was noted that while the hierarchical arrangement of biophysical (esp. structural vegetation) characteristics was relatively straight-forward, a similar effort in the land *use* domain is likely to be much more difficult, since the relative importance of management practices varies so widely across regions

5) While the harmonization of land COVER classifications has been a major undertaking, land USE poses an even greater challenge, not least because of a lack of consensus on the meaning of land use (is it the process that explains - and is explained by - land cover pattern, or does it encompass intentions, desires, attitudes, beliefs, constraints, opportunities, etc.?).

The workshop discussions revealed a lack of consensus on the precise definition of land use and concluded that the distinction between land *use* from land *cover* is still problematic. Getting land use researchers to agree on a fundamental set of land use attributes, from which classifiers can be operationalized, is going to be a MAJOR undertaking, since there is even difficulty distinguishing land uses from driving forces. The conflation of driving forces with land use is a significant issue. At the extreme, it is not always clear what is the "dependent variable" in land use studies. One school of thought holds that land uses cannot be usefully described without reference to the socio-environmental factors that govern the way the land is used (*e.g.,* access regime). The workshop participants felt that any harmonization would be incomplete if information on driving forces were not considered, and perhaps central. In fact, one view holds that the needs of the different research communities are so diverse that harmonization of all aspects of land use classification will ultimately be unsuccessful, and that effort should be focused solely on harmonizing information concerning the driving forces of land use.

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Workshop Participants

Frederic Achard
Coordinator, TREES Project
Global Vegetation Monitoring Unit
Space Applications Institute
EC Joint Research Centre
Italy

Etienne Bartholomé
Coordinator, GLC2000 Project
Global Vegetation Monitoring Unit
Space Applications Institute
EC Joint Research Centre
Italy

Alan Belward
Head, Global Vegetation Monitoring
Space Applications Institute
EC Joint Research Centre
Italy

Eduardo Brondizio
Asst Professor, Department of Anthropology
Research Associate, Center for the Study of Institutions, Population and Environmental Change
Indiana University
USA

Ruth DeFries
Associate Professor
Department of Geography and Earth System Science Interdisciplinary Center
University of Maryland
USA

Antonio DiGregorio
East Africa Project
Soil Resources, Management and Conservation Service
Environment and Natural Resources Service
UN Food and Agricultural Organization
Kenya

Hugh Eva
Global Vegetation Monitoring Unit
Space Applications Institute
EC Joint Research Centre
Italy

Bettima Fellmer
Advanced Methods Sector, Environmental and Geoinformation Unit
Space Applications Institute
EC Joint Research Centre
Italy

Günther Fischer
Leader, LUCC Focus 3
International Institute for Applied Systems Analysis
Austria

Andrew Hansen
Associate Professor, Department of Ecology
Montana State University
USA

Rheyna Laney
Assistant Professor, Department of Geography
Sonoma State University
USA

John S. Latham
Environment and Natural Resources Service
FAO Research, Extension and Training Division
Italy

Alejandro Leon
Doctoral Candidate
Arid Lands Resource Sciences Graduate Program
Office of Arid Lands Studies
University of Arizona
USA

Bill McConnell
LUCC Focus 1 Officer
Anthropological Center for Training and Research on Global Environmental Change
Indiana University
USA

Nkobi Moleele
Lecturer, Department of Environmental Science
University of Botswana
Botswana

Emilio F. Moran
Rudy Professor of Anthropology and Professor of Environmental Sciences
Director, Anthropological Center for Training and Research on Global Environmental Change
Co-Director, Center for the Study of Institutions, Population and Environmental Change
Leader, LUCC Focus 1
Indiana University

Vanda Perdigão
Global Vegetation Monitoring Unit
Space Applications Institute
EC Joint Research Centre
Italy

Rob Postma
Geographic Information Management, SA/NV
European Topic Centre on Land Cover
Belgium

Laura Schneider
Research Associate, Department of Geography and George Perkins Marsh Institute
Clark University
USA

Robert S. Thompson
Chief Scientist, Central Region Earth Surface Processes Team
U.S. Geological Survey
USA

Dalton de Morisson Valeriano
Remote Sensing Division, National Institute of Space Sciences
Brazil

Peter Verburg
Laboratory of Soil Science and Geology
Department of Environmental Sciences
Wageningen University
The Netherlands

Stephen J. Walsh
Professor, Department of Geography
Director, Spatial Analysis Laboratory, Department of Geography
Director, Spatial Analysis Unit, Carolina Population Center
Senior Research Fellow, Sheps Center for Health Services Research
University of North Carolina at Chapel Hill
USA